

Using Spectral Classification and Training Techniques to Identify Acid Mine Drainage Locations in Muddy Creek Watershed, West Virginia

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Abstract:

Acid mine drainage (AMD) sources from abandoned mines have not been systematically inventoried in West Virginia. This is an important task that West Virginia Department of Environmental Protection's (WVDEP's) Office of Abandoned Mine Lands and Reclamation (OAML&R) must accomplish to quantify the magnitude of the AMD problem throughout the state.

As a pilot project to identify acid mine drainage locations, the Remote Sensing Group of the Technical Applications and Geographic Information Systems (TAGIS) Unit was asked by OAML&R to develop a remote sensing-based method that would identify locations of AMD in the Muddy Creek watershed. This paper will focus on how functions of ERDAS IMAGINE and Environmental Systems Research Institute Inc.'s (ESRI's) ArcGIS's Spatial Analyst extension were utilized with three-band (red, blue, green) imagery to locate acid mine drainage discharges prior to going into the field. By allowing field teams to navigate directly to the vicinity of individual AMD discharge locations, time and money can be saved compared to methods previously used for cataloging AMD sites. This method could potentially be adapted to other aerial and satellite-based imagery sources. In the future, TAGIS will investigate implementing this method of identifying AMD using Leica's Image Analyst extension for ArcGIS.

This project is ongoing. Findings to date are presented to provide States/Tribes insights into WVDEP's work to remotely sense AMD sites prior to field verification.

Introduction:

In 1991 there were 66,500 documented sources of coal mine drainage in Appalachia, 3000-5000 active or abandoned coal piles and impoundments containing 3×10^9 metric tons of waste, resulting in the pollution of an estimated 17,000 km of streams (Cohen and Gorman, 1991). This project began because of the need to rapidly produce a statewide inventory of AMD in West Virginia. Acid Mine Drainage is a solution produced when oxygenated water comes in contact with the mineral pyrite (FeS_2) contained within certain coal-bearing rock strata disturbed or exposed through mining practices. Weathering of pyrite releases ferrous iron, sulfuric acid and often other heavy metals present as impurities within the mineral (Sawyer and McCarty, 1978; Krauskopf, 1979; and Drever, 1988). Acid mine drainage impacts watersheds through both point- and diffuse-source discharge processes. Point- source discharge is measurable flow at identifiable sources such as seepage from tailings, spoil, refuse or gob and artisan flow

produced by abandoned deep-mines. Diffuse-source discharge is effluent flow from large areas. The neutralization of AMD precipitates amorphous material, largely the oxy-hydroxides of iron, the so-called “yellow-boy”. Precipitation occurs as the leachate is oxidized by contact with air and where neutralized by alkaline solutions. Other precipitates produced by AMD are the oxy-hydroxides of aluminum and manganese, which are products of impurities within the mineral (Brown, 1996).

This project focused on identification of yellow-boy (by color) within a statewide image dataset, through the computer training of known AMD locations and processed for the entire image set. This approach, in theory, provides the ability to identify possible AMD point and non-point source discharge, because the analysis focuses on identification of an area. Existing statewide natural color orthophotography was the starting point for the development of the inventory because it is a high-resolution dataset (2 foot pixel) and was provided to the Agency via an E911 mapping and addressing project at no cost.

Study Site:

The Muddy Creek Watershed, in Preston County, West Virginia is a sub-watershed within the Cheat River basin. Martin Creek watershed is a smaller watershed within the Muddy Creek drainage. Geographically the Muddy Creek watershed is located within the Central Appalachian Ridge and Valley Province. This watershed was chosen as a pilot study area, because of the difficulties that field personnel had locating all sources of AMD. Much of the watershed is believed impacted by diffuse sources with the entire length of the stream walked without discovery of point source discharges. The watershed is full of old Abandoned Mine Land problems (AML) which are grown over with vegetation. No active mining is currently occurring, however there are two Special Reclamation sites treating acid runoff in the headwater region. Headwater pH is slightly acidic at 5.7, which is consistent with unpolluted watersheds in the region. The pH at the mouth is acidic with values as low as 3.5

Methods:

The West Virginia Statewide Addressing and Mapping Board (WVSAMB) 2003 true color imagery is roughly 1”=400’ scale and can be used to identify most surface flow. The idea was to utilize Leica’s ERDAS Imagine software and train the imagery to detect the possible locations of AMD by identifying Fe-bearing secondary minerals or “yellow-boy”. The spectral signature of yellow-boy would be identified using Imagine and matched with the training signature set derived from known AMD locations.

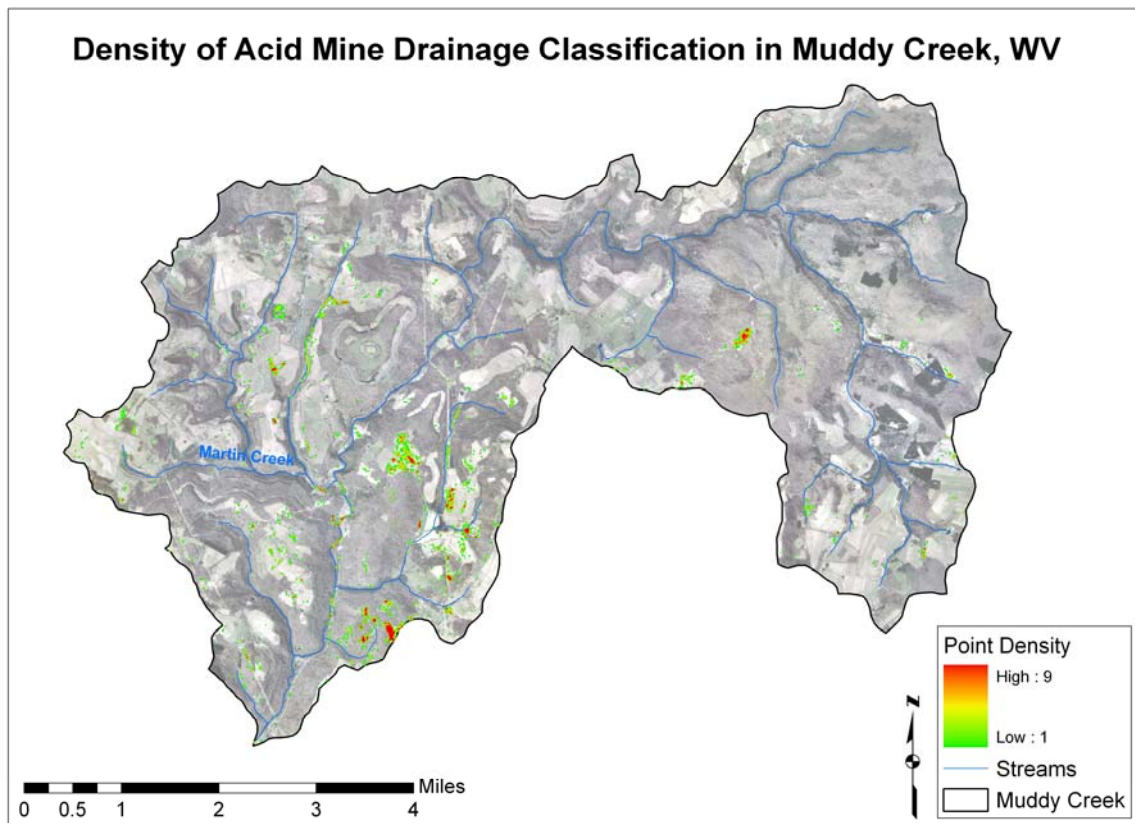
When the image classification was complete it was determined that there were too many false positives identified. Because re-training the data might un-classify real AMD locations, it was decided to run a smoothing algorithm to remove very small, scattered pixels identified as AMD by our classification workflow. To combat false positives and to improve the integrity of the AMD dataset, a Density Analysis was performed on the raw data. It was observed that known AMD locations had a higher concentration of identified AMD pixels. Due to this textural denseness, the researchers felt a Density Analysis would filter out less dense false positives.

To perform the Density Analysis the raster data set had to be converted to binary (AMD equal to 1, non-AMD equal to 0) data. Next it was converted from raster to vector format because the density tool in ESRI's ArcGIS Spatial Analyst software works with vector point data. The output results of the density analysis are a raster grid with weighted Density indicated on a scale of 1-9. Manipulation of the dataset via the density tool provided two improvements: (1) a general location to search for AMD and (2) intensity information.

Field Verification and Quantification:

The morning of April 27, 2006 a team of professionals assembled on Martin Creek, our selected sub-watershed of Muddy Creek, to determine the accuracy of the Density Analysis. Martin Creek was chosen because two treatment facilities were constructed in the headwater regions of the watershed. The stream's pH levels were: around 5.7 near the head (mildly acidic) and 3.5 near the mouth (acidic). Obviously there were sources of AMD between the headwater region and the mouth. A map showing the Density Analysis (see Map 1) was used to determine where in the watershed to begin field verification. It was decided to start at a location that had a moderate

Map 1: Results of Classification and Density Analysis



yellow-boy density profile. The team proceeded to that location. Upon arrival, there was no doubt that an unknown source of AMD had been discovered (see Image 1).



Image 1: AMD point source discharge running into refuse pile

A point source discharge poured on top of a refuse pile, which absorbed the AMD and deposited it diffusely into the stream. With no point source discharge and an overgrown refuse pile; it would have been virtually impossible to locate this source using only data training techniques. The team continued the field verification and found acid discharges (see Image 2) near each location on the map produced from the Density Analysis. Based on this limited pilot study, Density Analysis was successful at locating potential AMD discharges. West Virginia Department of Environmental Protection staff participating in the field verification effort indicated interest in expanding the use of the remote sensing techniques used in Martin Creek watershed by asking when this technique would be available for the Muddy Creek watershed to assist them in their AMD inventory effort. The Imagine classification was only applied to the more common iron precipitate. It was determined to be too difficult a task to identify aluminum and manganese using this methodology.

It is important to note that the Density Analysis does not necessarily locate individual seeps. Rather, the process weights the density of seep identification and puts



Image 2: AMD discharge location near headwaters of Martin Creek

different sources of imagery could produce misclassifications. The data-training component of the software uses Digital Numbers (DNs) and is not a true spectral signature; therefore using the signature file could yield erroneous results. The researchers did not calibrate the sensor with a field spectrometer to identify the actual spectral signature. Rather, we trained a color photo within a remote sensing software package.

Benefits:

The benefit in using these remote sensing processes is more accurate identifications of iron-discolored areas in a watershed that typically indicate AMD thereby saving time in the field. This technique does not replace the field staff, but allows them to be more productive while conducting their fieldwork. The team was able to navigate directly to the targeted areas without having to traverse the entire watershed looking for sources. At least four hours of unnecessary fieldwork was saved in this watershed by utilizing the Density Analysis in conjunction with aerial photos and topographic maps in this pilot project. This is time field personnel could have used to inventory other watersheds.

Individual Discharge Location Limitations and Recommendations:

The Density Analysis places the field staff in the relative location of areas with apparent AMD indicated by highly dense clusters of pixels that represent iron discoloration. This is an indirect method that cleans false positives from areas of interest. After the verification fieldwork was done, an evaluation of the raw data showed that individual discharge locations were also found. Using the two (the raw data and the density analysis) in conjunction may be the best approach. This would allow the field staff to navigate to the proper area using the Density Analysis and then locate individual discharge locations using the raw data.

Future Work:

Phase 2 of this study is to fly Martin Creek with a four-band Spectra-View 2k x 2k airborne digital imaging system in early November during leaf-off conditions. The sensor will provide around 10" pixel resolution compared to 24" resolution of the WVSAMB data. The sensor will also provide an additional band in the "near infrared" range of the electromagnetic spectrum. The near infrared data will provide the ability to create a water-mask (a technique used to identify water saturated areas), which will allow easier elimination of more false positives. The near infrared portion of the electromagnetic spectrum is absorbed by water and can, therefore, be separated from dry surfaces. After completion of that flight researchers will be able to determine if there is a benefit in running the Density Analysis on the Agency's sensor data. Production of a water-mask and better individual seep identification may prove to be adequate.

The potential exists for automation of part or all of the remote sensing techniques used in this study via construction of a customized geospatial application using ArcGIS.

Recently the Office of Surface Mining's (OSM's) Technical Innovation and Professional Services (TIPS) partnership with States/Tribes extended access to a limited number of licenses of Leica's Image Analyst extension for ArcGIS to all TIPS users. In the future WVDEP's researchers hope to collaborate with OSM TIPS personnel to create an ArcObjects-based toolbar that could be provided to other States/Tribes to assist them in updating their AMD inventories.

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